(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 815 985 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
07.01.1998 Bulletin 1998/02

(51) Int. Cl.[6]: **B21K 21/16**, B21D 26/02, B21C 23/14

(21) Application number: 97109605.2

(22) Date of filing: 12.06.1997

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: 21.06.1996 IT TO960536

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(54) **Method and apparatus for the hot-forming of tubular box-type elements of any shape made from a light alloy**

(57) Tubular boxes (2) of any shape are made from a light alloy (based on aluminium and/or magnesium for example) by means of a hot-forming method, preferably starting from billets (11) cast in that alloy, which provides a first phase in which the alloy is hot-extruded through a die (14) of suitable shape so as to be formed into a tube (4) of pre-determined section, preferably circular, generally rectilinear, a second phase in which the extruded tube (4), still hot, is fed between two moulds (6,7) which are heated and provided with conjugated cavities capable of defining with their contour the final shape of the box (2), and a third phase in which the extrusion (4) is pressed inside the moulds (6,7) which are brought close together in a fluid-tight manner, by creating a vacuum between extrusion (4) and cavity (8,9), inside the cavities (8,9), and conveying a pressurized gas inside the extrusion (4); during the second phase the moulds (6,7) are kept close together at a certain distance apart from each other so that the cavities define a guide channel for the extrusion (4) inside which it is caused to slide to obtain a pre-form of it; all the phases take place with the alloy kept at the temperature of maximum plasticity.

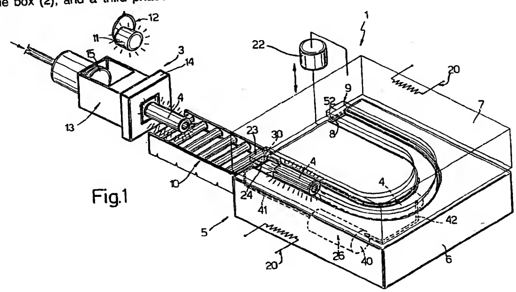

Fig.1

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Description

The invention relates to a method of carrying out the hot-forming of tubular box-type elements (simply called "boxes" below) made of a light alloy (based on aluminium and/or magnesium for example) having the most diverse and complex shapes, both in transverse section and in the longitudinal direction. Box-type elements of this kind are used in particular in the motor industry as structural elements of the body of vehicles. The invention also relates to an apparatus suitable for implementing the method according to the invention.

It is known to produce some box-type structural elements of the body of vehicles by means of extrusions formed from light alloy; the known elements can, however, be formed only with relatively simple shapes, both in transverse section and, above all, in the longitudinal direction; in fact, the extrusion operation enables blanks to be obtained which generally have only a rectilinear shape; to obtain curvilinear elements, therefore, the extrusions subsequently have to be bent, with expensive additional working operations and the risk of breaking them because of the hollow internal structure.

To date, therefore, box-type elements of complex shape have been obtained in sheet steel or another material which is easy to weld (in contrast to aluminium and light alloys in general) and produced precisely by longitudinal welding of several profiles of open transverse section. In this way, however, the boxes have high weights, which mean higher costs, greater fuel consumption and increased pollution.

The object of the invention is to overcome the disadvantages described, by providing a method that is relatively simple, inexpensive and which does not require complex or cumbersome pieces of equipment, to form box-type elements made of any light alloy available on the market in any form or shape, with a high degree of accuracy and the minimum of waste.

On the basis of the invention a method is therefore provided for the hot-forming of a tubular box of any shape made from a light alloy, comprising a first phase in which the alloy is hot-extruded through a die of suitable shape so as to be formed into a tube of pre-determined section and generally rectilinear, and a moulding phase, in which the extrusion is pressed, to obtain the box of desired shape, between at least two moulds provided with respective conjugated cavities capable of defining with their contour the final shape of the box; characterized in that during the said moulding phase, the said moulds are kept close to each other in a fluid-tight manner; the said moulds being heated so as to maintain the extrusion, during the entire moulding phase, substantially at the same temperature at which it left the first extrusion phase; the moulding phase being carried out by creating a vacuum between extrusion and cavities, inside the cavities, and conveying a pressurized gas inside the extrusion.

Furthermore, the method of the invention preferably also comprises a second phase in which the extruded tube, still hot, is fed between the said moulds provided with conjugated cavities, during this second phase the moulds being heated so as to maintain the extrusion substantially at the same temperature at which it left the first extrusion phase; during the second phase the moulds being kept close together at a certain distance apart from each other, so that the cavities define a guide channel for the extrusion, inside which the latter is caused to slide so as to obtain a pre-form of it. It is understood that the above-mentioned phases are carried out sequentially and in the shortest possible time.

In this way, an extrusion that is substantially rectilinear and of simple shape in transverse section may be pre-formed in the longitudinal direction into any desired shape (U, L, zigzag, etc., for example), obtaining the hot bending thereof without the risk of breaking the transverse section and without having to resort to suitable bending equipment, and can then be moulded into a shape of transverse section of any complex design (H, star, etc.), still without any risk of breaking its transverse section.

The invention also relates to an apparatus for the hot-forming of a tubular box of any shape made from a light alloy, comprising an extrusion station capable of providing a tubular extrusion of pre-determined section and generally rectilinear, and a moulding station comprising at least two moulds provided with respective conjugated cavities capable of defining with their contour the final shape of the box to be obtained; characterized in that the said moulding station is arranged immediately downstream of the extrusion station, to receive said extrusion leaving the extrusion station directly between said moulds; the said moulds being provided with heating means and the moulding station also comprising:

- means for keeping the moulds selectively arranged in two different operating positions, in a first of which the moulds are close together at a certain distance apart from each other, so that the cavities define a guide channel for the extrusion provided with a through open end facing the extrusion station and through which the extrusion is capable of sliding in the channel so as to be pre-formed by it; and in a second of which the said moulds are kept close together in a fluid-tight manner; and
- means which can be actuated in the said second operating position of the moulds to create a vacuum between extrusion and cavities, inside the cavities, and to convey a pressurized gas inside the extrusion.

This and other features of the invention will be described in greater detail in the description which follows of a preferred embodiment which is given by way of non-exhaustive example with reference to the accompanying drawings, in which:

- Fig. 1 shows a diagrammatic view of the apparatus of the invention during the performance of some phases of the method according to the invention;
- Fig. 2 shows a detail of Fig. 1 on an enlarged scale and, diagrammatically, a further phase of the method of the invention, and
- Fig. 3 shows an exemplary transverse section of box obtainable according to the invention, compared with the overall dimensions of an extrusion from which it can be obtained, illustrated in dashed lines together with the profile of the cavities of two moulds brought close together for the pre-forming of the extrusion.

With reference to Figs. 1 to 3, in its entirety 1 shows an apparatus which can be used according to the invention to obtain the hot-forming of a tubular box 2 of any shape (in the non-exhaustive example shown the box 2 is U-shaped in longitudinal direction and rectangular transverse section) made of any light alloy.

The apparatus 1 comprises an extrusion station 3, of known type, capable of carrying out a first phase, that of extrusion, of the method of the invention to provide a tubular extrusion 4 of pre-determined section (circular in the non-exhaustive case shown) and generally rectilinear, and a moulding station 5 (capable, as will be seen, of carrying out a second and a third phase of the method of the invention) comprising at least two moulds 6, 7 (of which 7, the top one, is shown in Fig. 1 in a phantom view, so that the bottom mould 6 can be seen) provided with respective conjugated cavities 8, 9 (see also Fig. 3) capable of defining with their contour the final shape of the box 2 to be obtained (in this case the cavities 8, 9 are configured in a U on plan and have a rectangular transverse section).

According to the invention, the moulding station 5 is arranged immediately downstream of the extrusion station 3, to receive the extrusion 4 leaving the extrusion station 3 directly between the moulds 6, 7, so that when the extrusion begins to be worked in the station 5 it is still substantially at the same temperature at which it left the station 3; for this purpose, for example, the two stations 3 and 5 are arranged adjacent to one another and are connected by conveying means, such as a motor-driven roller conveyor 10, which is known, and which is capable of taking the extrusion 4 when it leaves the station 3 and causing it to advance, with pre-determined force, towards and inside the station 5. It is clear, therefore, that the stations 3 and 5 could also be adjacent or contiguous, and in this case the conveying means, particularly the roller conveyor 10, would be of dimensions which are reduced or actually absent, the feed force being conveyed to the extrusion directly by the action of the extruder.

The station 3 is preferably of the type that is capable of being fed with billets 11 of pre-determined dimensions and weight, obtained directly from the molten light alloy; these billets 11 are obtainable on the market and are fed to the station 3 in known manner, by means of handling devices 12, after having been pre-heated in a furnace to a pre-determined temperature which is suitable for rendering plastic (under suitable pressure) the alloy from which they are formed; in particular the station 3 includes an extrusion press 13, which is known, and illustrated solely in diagrammatic form, into which the red-hot billets (as is illustrated pictorially in Fig. 1) are introduced one at a time, and a matrix (or die) 14, which is known, and shaped in the shape which it is desired to impart to the transverse section of the extrusion 4 leaving the station: in practice, the billet 11, brought to the temperature of maximum plasticity specific to the alloy of which it is made, and once it has been introduced into the press 13 (which is preferably of the heated type), is subjected to an extremely high compression from a ram 15 of the press 13, which brings the alloy of which the billet 11 is composed into a fluid state, including if of high viscosity, which enables the alloy to flow through the die 14, receiving the desired shape from it and thus supplying, at the exit from the station 3, a solid pre-form (in the sense that it is capable of maintaining its own shape including under load and it can be handled mechanically), including if still red-hot, comprising the extrusion 4.

According to the method of the invention the extrusion phase, like every successive phase also, is carried out at the temperature of maximum plasticity of the alloy, and the extrusion 4 is formed as a tube which is substantially rectilinear and of substantially circular transverse section. More specifically, all the phases of the method of the invention are carried out whilst maintaining the alloy at a temperature at which it is in a semi-solid state, or it is within its solidification range and contains a liquid phase fraction lower than 50% by weight. According to a possible variant, however, at least the extrusion phase could also be carried out at a higher temperature, starting, for example, directly from the melt as well as from billets 11, in which case a different press 13 will be used and the die 14 will be of the cooled type, so as to ensure, however, at the exit from the station 3, the supply of an extrusion 4 which is at the temperature of maximum plasticity of the alloy used.

According to the invention the moulds 6, 7 of the station 5 are made of material that is a good conductor of heat and are provided with heating means, shown diagrammatically by 20 and capable of keeping them and, consequently, the blank 4 fed between them substantially at the same temperature at which it left the station 3, or at the above-mentioned temperature of maximum plasticity of the alloy used; the means 20 may be electrical resistors or, preferably, coils in which an oil (or another diathermic fluid heated in a suitable boiler which is not shown) is made to circulate.

Still according to the invention, furthermore, the moulding station 5 comprises actuating means 22

(comprising, for example, a hydraulic press with appropriate limit switches, shown solely in diagrammatic form with a block) capable of moving the moulds 6, 7 relatively in the direction of the arrow (Fig. 1) - generally speaking the mould 6 will be stationary and the mould 7 will be moved so that it is brought close to/moved away vertically from the mould 6 - to keep the moulds 6, 7 selectively arranged in two different operating positions.

A first operating position is that shown in Figs. 1 and 3, in which the moulds 6, 7 are arranged exactly superimposed, but only semi-close together, i.e. close together at a certain distance D apart from each other (Fig. 3) so that the facing cavities 8, 9 define between them an open guide channel 23 (in this case U-shaped on plan) for the extrusion 4; the cavities 8, 9 are also produced in such a way that the channel 23 is provided with at least one through open end 24 (see also Fig. 2) which is arranged in correspondence to the roller 10, facing towards the extrusion station 3, and through which the extrusion 4 leaving the station 3 can be introduced into the channel 23 to be caused to slide inside it, guided, for example, in contact with the bottom walls and/or the longitudinal corners of the semi-close together cavities 8, 9.

In contrast the second operating position which the moulds 6, 7 can assume is not shown, insofar as it corresponds simply to the first, but in which the distance D is reduced to zero, so that the moulds 6, 7 are kept close together with a pre-determined pressure; in particular, according to the invention the moulds 6, 7 are configured (or equipped, as will be seen) in such a way that in this second operating position they are close together not only in contact but also in a perfectly fluid-tight, particularly gas-tight, manner.

Finally the station 5 comprises pneumatic means, shown diagrammatically by 26, which are arranged, for example, incorporated inside (or underneath or adjacent to) the stationary mould 6, can be actuated solely in the second operating position of the moulds 6, 7 and are capable both of creating the vacuum inside the cavities 8, 9 between the extrusion 4, previously introduced into the channel 23, and the cavities 8, 9 themselves, and of conveying a pressurized gas inside the extrusion 4 which is present between the moulds 6, 7. In order to prevent possible corrosive phenomena of the extrusion 4, this gas is preferably an inert gas, such as helium, argon or nitrogen.

According to the method of the invention, once a substantially traditional extrusion phase has been carried out in the station 3, which produces an extrusion 4 of simple shape, so that the extrusion phase can be carried out at low cost, high speed and efficiency and with no waste, a phase of pre-forming or blocking towards the definitive shape desired for the box 2 is then carried out on the extrusion 4. For this purpose the block or blank which the tubular extrusion 4 constitutes is taken from the die 4 and immediately fed continuously, still hot, between the two moulds 6, 7 arranged in the above-mentioned first operating position, inside the curved channel 23 defined by the cavities 8, 9.

Thanks to the fact that the extrusion 4 is still at the temperature of maximum plasticity of the alloy which forms it (which is variable with the composition of the alloy and is therefore specific to each alloy used at any given time) and to the fact that it is maintained at this temperature by the means 20, the extrusion 4 is pre-formed by the effect of its sliding, with gradual introduction, in the channel 23 of which it will tend to assume the shape, in particular the extrusion 4 will be bent into a U (dashed section in Fig. 1) or into any other shape corresponding to the shape on plan of the cavities 8, 9.

When the introduction of the extrusion 4 into the channel 23 is completed, i.e. after the second phase, a third phase of the method of the invention is carried out which comprises a moulding phase of the already pre-formed extrusion into the definitive dimensions and shape of the box 2 to be obtained. Before this third phase is carried out, however, a cutting phase (Fig. 2) is carried out in which the pre-formed extrusion 4 in the channel 23 is cut in correspondence with the through open end 24 of the channel 23, by means of a bulkhead with shears 30, for example, which is made to ascend from a seat (not shown) provided in the mould 6 to intercept and close the end 23.

This same bulkhead 30 is produced in such a way that it is also capable of sealing the end 23 in a fluid-tight manner immediately after having carried out the cutting phase; alternatively, this closing function may be performed by any other known mobile sealing means, such as another sliding bulkhead, an expanding sleeve etc. In any event, immediately after the cutting phase (or also at the same time as it takes place) the moulds 6, 7 are brought together into contact, gradually reducing the distance D between them, until they are pressed against each other in a fluid-tight manner; in this configuration (Fig. 2) the bulkhead 30 (or means equivalent to it) will not only close the open end of the moulds 8, 9 in a fluid-tight manner but also the internal volume of the pre-formed extrusion 4, whose corresponding open end, or that just cut, will be coupled in contact with the bulkhead 30 (or with the possible sealing means which will have taken the place of the bulkhead/shears 30 after the cutting phase).

It is obvious that by bringing the moulds 6, 7 close together into contact, the cavities 8, 9 are also brought into contact, obtaining the deformation in the radial direction of the blank constituted by the extrusion 4, which is consequently subjected to the phase of moulding into the box 2 to be obtained. According to the invention, the moulding phase is not, therefore, carried out in traditional manner, simply by bringing the moulds 6, 7 into contact, but, profiting from the fact that the latter are brought close together in a fluid-tight manner and that, also once the moulds 6, 7 are close together the extrusion 4 is kept by the heating means 20 at the temperature of maximum plasticity of the alloy being worked, so

that it is highly deformable, the moulding phase is carried out by creating a vacuum between extrusion 4 and cavities 8, 9, inside the cavities 8, 9 themselves, and by conveying a pressurized gas inside the extrusion 4.

For example, for this purpose the pneumatic means 26 include a double pump 40 and two pipes 41 and 42; the pipe 42 has an outlet (or a series of outlets, consequent on a possible bifurcation of it, which is not shown for reasons of simplicity) inside the cavities 8 and/or 9, whereas the pipe 41 extends partly inside the bulkhead 30, or in such a way as to have an outlet 44 facing, with moulds 6, 7 close together in contact, the internal cavity of the extrusion 4, in correspondence with one of its two opposite terminal ends, in the case illustrated one end 50 (Fig. 2) corresponding to the open end 24 (now closed by the bulkhead 30) of the channel 23. The opposite end (not illustrated for reasons of simplicity) of the extrusion 4 will now be sealed fluid-tight, either because it rests against closed and adjacent ends 52 (Fig. 1) of the cavities 8, 9 opposite the ends defining the open end 24, or because this end also of the extrusion 4 will be kept closed by a mobile bulkhead of the moulds 6, 7.

During the moulding phase according to the invention, therefore, the pressurized gas (inert gas such as argon, helium or nitrogen at 100 atmospheres, indicated by the small arrows in Fig. 3) fed inside the extrusion 4 through the channel 41 will tend to "inflate" it, producing the deformation of its lateral wall (the alloy forming the extrusion 4 is in fact in a plastic state) which is squeezed to copy the profile of the cavities 8, 9, whilst a similar effect will be achieved by the extraction of the air present in the cavities 8, 9 (only shown in diagrammatic form in Fig. 3 by small arrows pointing towards the pipe 42), which enables the plastic walls of the extrusion 4 in deformation phase to copy the walls of the cavities 8, 9 without air bubbles being interposed to produce surface defects.

Once a desired degree of vacuum has been reached inside the cavities 8, 9 and/or a desired pressure inside the blank 4, or a pre-determined time has elapsed, the heating means 20 are de-activated and the moulds 5, 6 moved apart to a distance greater than D and such as to enable the box 4 thus obtained to be extracted from them as soon as it has cooled down sufficiently.

By operating as described, starting from billets of aluminium alloy of the following composition by weight: 0.95% Si, 0.17% Fe, 0.5% Mn, 0.65% Mg, remainder Al, produced by Hydro Aluminium Sunndal (Norway), work is carried out in all the phases (extrusion, pre-forming and moulding) at the temperature of 575 °C, using an extrusion pressure of 1000 tonnes and carrying out the moulding at a gas pressure inside the blank of 100 atm and at industrial pressure on the outside, so as to eliminate the air space usually present between moulds and blank in a normal moulding phase. Tubular boxes of different shapes which are perfect and free from defects have been obtained in trials.

The technology of the invention can therefore be used for any light alloy and in particular for the alloys of aluminium (Al) such as: Al/copper, Al/silicon, Al/magnesium, Al/zinc alloys; and for magnesium (Mg)-based alloys such as: Mg/aluminium, Mg/aluminium/zinc, Mg/zinc/rare earths.

Claims

1. Method for the hot-forming of a tubular box of any shape made from a light alloy, comprising a first phase in which the alloy is hot-extruded through a die of suitable shape so as to be formed into a tube of pre-determined section and generally rectilinear, and a moulding phase, in which the extrusion is moulded, to obtain the box of desired shape, between at least two moulds provided with respective conjugated cavities capable of defining with their contour the final shape of the box; characterized in that during the said moulding phase, the said moulds are kept close to each other in a fluid-tight manner; the said moulds being heated so as to maintain the extrusion, during the entire moulding phase, substantially at the same temperature at which it left the first extrusion phase; the moulding phase being carried out by creating a vacuum between extrusion and cavities, inside the cavities, and conveying a pressurized gas inside the extrusion.

2. Method according to Claim 1, characterized in that it also comprises a second phase in which the extruded tube, still hot, is fed between the said moulds provided with conjugated cavities, during this second phase the moulds being heated so as to maintain the extrusion substantially at the same temperature at which it left the first extrusion phase; during the second phase the moulds being kept close together at a certain distance apart from each other, so that the cavities define a guide channel for the extrusion, inside which the latter is caused to slide so as to obtain a pre-form of it.

3. Method according to Claim 2, characterized in that the said moulding phase is carried out after the said second phase, that of pre-forming, so as to constitute in sequence solely a third phase of the forming cycle of the box to be obtained; all the said phases being carried out with the alloy being kept in a temperature range around the temperature of maximum plasticity specific to the alloy used.

4. Method according to Claim 2 or 3, characterized in that the said second phase is carried out immediately downstream of the first phase, feeding the extrusion leaving the die directly between the said semi-close together moulds and producing the lat-

ter in such a way that the said guide channel defined by said cavities of the moulds terminates towards the said die with a through open end.

5. Method according to Claim 4, characterized in that after the second phase and before bringing the moulds close together in a fluid-tight manner to carry out the said moulding phase, the said extrusion is cut in correspondence with the said through open end of the guide channel defined by the cavities of the moulds; during the said moulding phase, the said open end of the channel and the internal volume of the said extrusion are closed in a fluid-tight manner by mobile sealing means.

6. Method according to one of the preceding Claims, characterized in that the said first phase, that of extrusion, is carried out starting from billets cast in the light alloy of which it is desired to obtain the box, which billets are heated to the temperature of maximum plasticity of the alloy and then introduced into an extrusion press one at a time.

7. Method according to Claim 6, characterized in that the said extrusion is formed as a tube of substantially circular transverse section.

8. Method according to one of the preceding Claims, characterized in that all the said phases are carried out with the alloy being kept at a temperature at which it is in a semi-solid state, or it is within its solidification range and contains a liquid phase fraction less than 50% by weight.

9. Apparatus for the hot-forming of a tubular box of any shape made from a light alloy, comprising an extrusion station capable of providing a tubular extrusion of pre-determined section and generally rectilinear, and a moulding station comprising at least two moulds provided with respective conjugated cavities capable of defining with their contour the final shape of the box to be obtained; characterized in that the said moulding station is arranged immediately downstream of the extrusion station, to receive said extrusion leaving the extrusion station directly between said moulds; the said moulds being provided with heating means and the moulding station also comprising:

- means for keeping the moulds selectively arranged in two different operating positions, in a first of which the moulds are close together at a certain distance apart from each other, so that the cavities define a guide channel for the extrusion provided with a through open end facing the extrusion station and through which the extrusion is capable of sliding in the channel so as to be pre-formed by it; and in a second of which the said moulds are kept close together in a fluid-tight manner; and
- means which can be actuated in the said second operating position of the moulds to create a vacuum between extrusion and cavities, inside the cavities, and to convey a pressurized gas inside the extrusion.

10. Apparatus according to Claim 9, characterized in that the said moulding station also comprises mobile sealing means capable, in said second operating position of the moulds, of sealing in a fluid-tight manner the said through open end of the channel and the internal volume of the said extrusion.

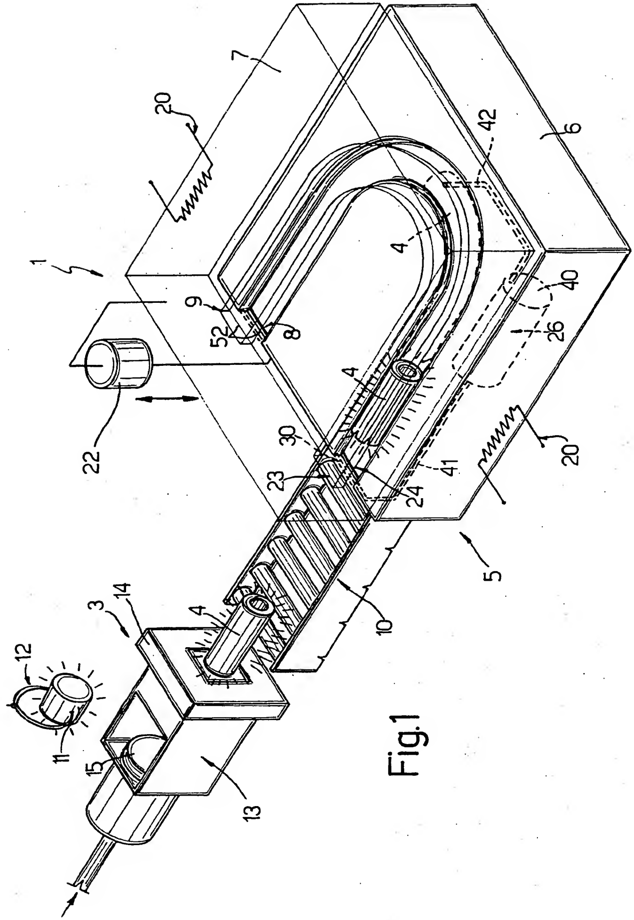
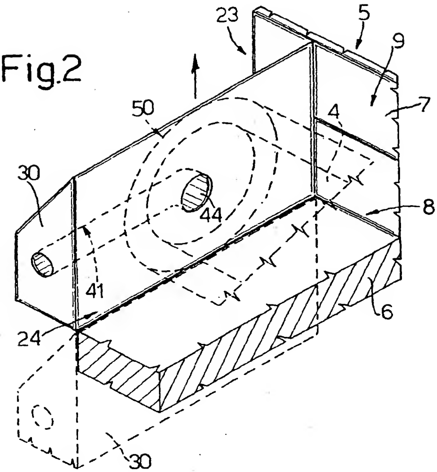


Fig.1

Fig.2



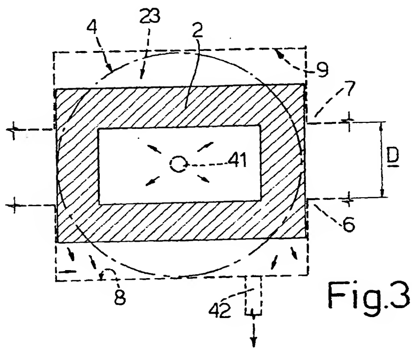


Fig.3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 10 9605

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
P,X	EP 0 727 343 A (GEN MOTORS CORP) 21 August 1996 * column 6, line 10 - line 30 * * column 7, line 23 - column 8, line 35; claims 4,12-14; figures *	1-11	B21K21/16 B21D26/02 B21C23/14
Y	PATENT ABSTRACTS OF JAPAN vol. 010, no. 207 (M-500), 19 July 1986 & JP 61 049735 A (RYODA SATO), 11 March 1986, * abstract *	1	
Y	PATENT ABSTRACTS OF JAPAN vol. 013, no. 013 (M-783), 12 January 1989 & JP 63 224857 A (KAWASAKI HEAVY IND LTD), 19 September 1988,	1	
A	* abstract *	6-8	
A	PATENT ABSTRACTS OF JAPAN vol. 017, no. 043 (M-1360), 27 January 1993 & JP 04 262819 A (SHOWA ALUM CORP), 18 September 1992, * abstract *	1-4,6,7,9	TECHNICAL FIELDS SEARCHED (Int.Cl.6) B21K B21D B21C
A	PATENT ABSTRACTS OF JAPAN vol. 95, no. 002 & JP 07 032076 A (MITSUBISHI ALUM CO LTD;OTHERS: 02), 3 February 1995, * abstract *	1	
A	EP 0 294 034 A (TI AUTOMOTIVE DIVISION) * claims 1,2; figures *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 September 1997	Barrow, J

CATEGORY OF CITED DOCUMENTS

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